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Inventor:—JAMES WILLIAM WALLEY.

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COMPLETE SPECIFICATION.

Improvements relating to Magnetic Coupling Devices including Clutches and Brakes.

We, METROPOLITAN-VICKERS ELECTRICAL COMPANY LIMITED, a British Company, having its Registered Office at St. Paul's Corner, 1—3 St. Paul's Churchyard, London, E.C.4, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to magnetic clutches, brakes and other such coupling devices of the kind in which two relatively rotatable co-operating parts maintained in spaced relationship with respect to each other are arranged to be coupled together, namely for the transmission of torque therebetween, by the coupling action of a magnetic field (or fields) set up between a pair (or respective pairs) of opposite poles so disposed in the one part of the device that magnetic flux passing from the one pole to the other traverses the space separating the co-operating parts and links the alternate part. As is well known such coupling action can be obtained by arranging the magnetic field to set up a hysteresis or an eddy current effect or by including in the space between the co-operating parts of the coupling device a magnetic fluid that will tend to become "solidified" on application of a magnetic field thereto.

In using such a coupling device as, for instance, a clutch between two relatively rotatable members, the two co-operating parts of the device will be arranged for rotation respectively with said members, whereas in using the device for braking a rotating member, one of the co-operating parts will be arranged for rotation with that member and the other part will be fixed against rotation. In the following, the term running member will be used to denote a member from which torque is to be transmitted by the coupling device, whether the transmitted torque is applied to drive a further member or is absorbed by a fixed member to effect a braking action on the running member.

It is often desirable that the extent of the coupling effect provided by a coupling device of the above kind, and thus the braking or driving torque transmitted by the device, shall be controllable in dependence on the speed of the running member, and to this end it has previously been proposed to provide the magnetic field by electromagnetic means and to control the excitation thereof in dependence on said speed. Such control has been obtained for instance by deriving a voltage proportional to speed, as from a permanent magnet generator rotating with the running member, and using that voltage to actuate an electronic device which in turn controls the exciting current for the electromagnetic means.

Speed dependent magnetic coupling devices of the kind referred to have also been proposed employing one or more permanent magnets the radial position of which is controlled in accordance with speed to provide a variable magnetic coupling. The present invention aims to provide an improved speed dependent permanent magnet coupling device by arranging for the radial position of one or more permanent magnets, or of pole pieces associated therewith, to be varied under direct centrifugal action thereon.

According to the present invention in a magnetic coupling device of the kind referred to the part thereof adapted for rotation with a running member (as defined) includes for rotation therewith one or more

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permanent magnet assemblies (each) arranged to provide opposite poles for a magnetic coupling field and (each) having at least a portion thereof arranged to move under the combined influence of centrifugal force and an opposing spring force between radially displaced positions at which, respectively, maximum and minimum linkage of magnetic flux with the alternate part of the device is obtained, such maximum and minimum linkage corresponding to maximum and minimum coupling effect respectively.

The coupling device may be arranged either to give increasing coupling effect with increasing speed or to give decreasing coupling effect with increasing speed (and vice versa) as may be desired.

The coupling device of the invention thus provides a magnetic coupling effect varying in dependence on the speed of a running member from which torque is to be transmitted, without requiring the use of intermediate electric or electronic means for controlling the excitation of an electromagnet. Also, since the coupling device operates by a centrifugal effect without relying on friction between the co-operating parts thereof for transmitting the torque, it has the advantage that wear between the parts can be substantially reduced as compared with conventional centrifugal brakes or clutches in which spring-loaded masses on the running member are caused by centrifugal force to move radially until they engage a cylindrical surface provided on the alternate member and thereby effect a frictional coupling. Moreover as will appear later it is possible with the coupling device of the invention to obtain flexibility of control which is greater than that obtainable with such conventional centrifugal devices operating by friction.

In one way of carrying out the invention the or each permanent magnet assembly may comprise a permanent magnet arranged for radial movement under the combined action of said centrifugal and opposing forces towards and away from a co-operating, generally cylindrical surface provided on the alternate part of the coupling device coaxially with the rotational axis, the magnet, or pole pieces secured therewith, providing opposite poles at positions spaced transversely of the magnet's movement whereby in the positions of the magnet corresponding to the poles being nearest to and furthest from said surface, there is respectively maximum and minimum linkage of flux with said alternate part of the device and thus maximum and minimum coupling effect.

To this end the magnet may be slidably assembled on the appertaining part of the coupling device on a radially extending rod or the like surrounded by a spring for opposing the action of centrifugal force on the magnet. Alternatively, especially where the coupling device is to constitute a brake, the magnet may be mounted on and intermediately of a spring strip or the like which is carried by the appertaining part of the device in position extending generally lengthwise of the rotational axis and is secured for axial sliding adjacent its opposite ends so as to bow to an extent dependent on the centrifugal force and the strength of the spring and thereby move the magnet radially to a corresponding extent.

It is also contemplated that the permanent magnet may be radially fixed with pole pieces permanently excited thereby arranged for radial movement as described for the magnet.

In another way of carrying out the invention the or each permanent magnet assembly on one part of the coupling device may comprise as separate parts of the assembly a permanent magnet and a pole piece assembly therefor including a pair of pole pieces magnetically isolated from each other, the magnet and the pole piece assembly being arranged for radial movement relatively to each other, under the influence of spring-opposed centrifugal force, between relative radial positions at one of which the magnet induces in the pole pieces a maximum flux producing therebetween a maximum coupling field linking the alternate part of the coupling device, and at the other of which the magnet induces minimum flux in the pole pieces. Preferably, in this latter relative position of the magnet and pole pieces the magnet poles are bridged by a magnetic shunt to ensure negligible magnetic field between the pole pieces.

With such arrangement the pole piece assembly of the or each permanent magnet assembly may comprise two composite, radially extending members between which the magnet is disposed, for relative movement with respect thereto, with its magnetic axis extending in the direction from the one composite member to the other, which members each comprise radially inner and outer portions of magnetic material separated by a substantially non-magnetic portion, with one pair of corresponding magnetic portions in the respective members, namely the outer or inner portions as may be appropriate, arranged to constitute the required pole pieces and with the other pair of corresponding magnetic portions magnetically connected through a magnetic cross-piece, so that when the magnet is in position between the pair of magnetic portions constituting the pole pieces poles are induced therein to produce the magnetic coupling field, whereas when the magnet is in position between the other pair of magnetic portions substantially all the flux from the magnet is shunted through the cross-piece. The pole piece assembly

may be radially fixed and the magnet arranged to be moved radially under the combined influence of centrifugal and opposing spring force, or alternatively the magnet may be radially fixed and the pole piece assembly arranged to be moved radially under the influence of said forces, in which latter case it will usually be arranged that the spacing of the pole pieces from the alternate part of the coupling device remains substantially constant throughout their movement.

The coupling characteristics obtained with a device in accordance with the invention depends on a number of factors by separate or combined adjustment of which a variation of performance can be obtained. Thus the coupling characteristics will depend on:

(1) the magnet strength,

(2) the shape of the magnetic poles or of the space traversed by the flux between the co-operating parts of the device, variation in these producing a variety of flux-to-gap-length characteristics,

(3) the strength and design of the spring(s) providing the force opposing the centrifugal force,

(4) whether or not air bleed or pneumatic damping is provided for,

(5) the weight of the parts moving under centrifugal action, it being contemplated that this can be adjusted if desired by the addition of non-magnetic weights to such parts.

It is contemplated that usually a plurality of permanent magnet assemblies as above described will be symmetrically disposed about the rotational axis of the coupling device. Moreover it may sometimes be useful to have a number of magnet assemblies, or sets thereof, arranged to become effective to produce their maximum coupling effects at different speeds so that with increasing (or, alternatively, decreasing) speed, the various assemblies or sets will attain their maximum coupling effects in turn, until at a predetermined high (or, in the alternative, low) speed all are contributing to a total maximum coupling effect. Furthermore in the case of an eddy current coupling device in accordance with the invention, a number of magnet assemblies, or sets thereof, may be arranged so as to have different effective diameters: since the eddy current drag is proportional to relative peripheral speed, each assembly, or set, will come into operation at different relative angular speeds of the running member with respect to the member to be coupled therewith.

For a fuller understanding of the invention reference may now be had to the drawings accompanying the Provisional Specification which illustrate various examples of coupling device in accordance with the invention and in which, in particular:—

Figs. 1 and 2 illustrate a magnetic clutch according to the invention, Fig. 1 being a section on the line X—X of Fig. 2;

Fig. 3 illustrates a magnetic brake according to the invention;

Figs. 4 and 5 illustrate an alternative arrangement to that of Figs. 1 and 2, Fig. 4 being a section on the line Y—Y of Fig. 5;

Figs. 6 and 7 illustrate respectively possible ways in which the arrangement of Figs. 4 and 5 could be modified to provide different coupling characteristics; and

Figs. 8, 9 and 10 illustrate further alternative arrangements for a magnetic clutch in accordance with the invention.

In Figs. 1 and 2 a number of U-shaped permanent magnets 1 are able to move radially with respect to a driving shaft 2 along non-magnetic guides 3, the movement of the magnets being controlled by springs 4 which abut against stops 5 at the ends of the guides 3 remote from the shaft. When the driving shaft is stationary, the magnets, under the restraining action of the springs, assume the inner positions as shown in the figures, but when the driving shaft is rotated, the centrifugal force acting on the magnets will cause them to slide along the guides 3, thereby decreasing the width of the gaps between the poles of the magnets and a cylindrical portion 6 formed integrally with a flange 7 carried by a shaft 8 to be driven. Thus as the speed of the driving shaft increases the amount of magnetic flux crossing the gaps to link the portion 6 will also increase thereby in turn to increase the coupling effect and thus the torque transmitted to the shaft 8. It will be noted that the relation between the speed and the torque will be non-linear since the force moving the magnets is proportional to the square of speed and the flux increases rapidly as the gaps diminish in width. Thus, the driving torque is proportional to an nth power of speed where n is greater than unity and may be, say, 3 or 4.

It will be appreciated that if the rimmed flange 7 were fixed against rotation, or if it were replaced by, say, a fixed cylinder surrounding the magnet assemblies, an increasing braking torque would be applied to the shaft 1 with increasing speed thereof, the torque being again proportional to, say, the third or fourth power of the speed.

Fig. 3 illustrates the invention incorporated in a brake. U-shaped magnets 9 are bolted to leaf springs 10 the ends of which are fastened to two collars 11, 12 keyed to, but slidable axially on, a rotatable shaft 13 to be braked. The magnets are surrounded by a fixed metal cylinder 14 which acts in conjunction with the magnets to provide a braking effect of magnitude dependent among other factors, on the width of the gaps between the magnet poles and the cylinder 14. Grooves 15, 16 of limited

length are provided on the shaft to engage with keys on the collars 11 and 12 thereby preventing the collars from rotating with respect to the shaft and also preventing the magnets from touching the cylinder 14.

It may be desirable in certain cases to have negligible drag or drive up to a certain speed, and a full braking effect or driving torque at speeds above that critical value. This may be obtained by an arrangement on the lines of that shown in Figs. 4 and 5, which arrangement constitutes a clutch but could readily be modified as a brake. In these Figures each of a number of permanent magnets 17 is constrained to move radially, with respect to a driving shaft 18, by pegs 19 engaging with slots 20 in radially extending members 21 of a pole piece assembly for the magnet, the movement of the magnets being controlled by springs 22 which react against fixed non-magnetic parts 23 at the outer ends of the members 21. The members 21 are composite members comprising radially inner and outer portions, 24 and 27 respectively, which are of magnetic material such as mild steel and are separated from each other by non-magnetic portions 26 as of brass. When the driving shaft is stationary the magnets assume the positions shown and substantially all of the magnetic flux from the magnet circulates through the inner portions 24 of the members 21 and a magnetic cross-piece 25, the portions 26 of non-magnetic material preventing the flux from reaching the outer portions 27 of the members 21. However, as the speed of the driving shaft increases, the magnets 17 move out radially against the springs until, at a certain speed, they pass the non-magnetic sections 26 and induce opposite poles in the appertaining outer portions 27 which then constitute pole pieces for the magnets and provide a magnetic flux linking a rimmed flange 28 on the driven shaft 29 and thereby reducing a coupling effect driving the shaft 29. Similarly, when the speed of the driving shaft decreases, the coupling decreases until the magnets pass the portions 26 when the coupling becomes negligible. The characteristics of this drive may be adjusted by the methods listed above and also by suitably shaping the magnets and the pole pieces, Figs. 6 and 7 showing two examples of this in diagrammatic form.

The arrangements described in connection with Figs. 1—5 are such as to give increased coupling effect with increased speed. It is also contemplated that the coupling effect could be arranged to be a minimum at high speed and a maximum at low speeds and possible ways of doing this are illustrated in Figs. 8—10.

Figs. 8 and 9 are merely inversions of the arrangements of Figs. 1 and 4 respectively and their construction and operation will be readily understood without further description. The arrangement of Fig. 10 is similar to that of Fig. 9 except that the magnets 17^1 are radially fixed while the composite radially extending members 21^1, which are similar to the corresponding members 21 of Fig. 4 in that they have radially inner and outer magnetic portions 24^1 and 27^1, an intermediate non-magnetic portion 26 and a cross-piece 25^1, are constrained to move outwardly against a spring action under the influence of centrifugal force. It will be noted in Fig. 10 that the members 21^1 are arranged so that the outer ends of the portions 27^1 (namely at which the poles are induced) move between the flange 7^1 and an inwardly extending flange 30 in such manner that the gaps at the poles remain substantially constant throughout the movement of the members 21^1.

The arrangement illustrated in the various Figures of the drawings may be arranged in known manner so as to provide the required coupling either by a hysteresis effect or by an eddy current effect or by a combination of these. Alternatively or in addition the gaps between the poles set up in the one part of the coupling device and the alternate part of the device may be filled with a magnetic fluid such as will tend to "solidify" to provide a coupling effect on the application of a magnetic field thereto. Suitable materials for the permanent magnets are those known by the names "Alcomax" (a Registered Trade Mark) and "Columax".

As is well known, if a magnet is moved from a circuit of low magnetic reluctance to one of relatively high reluctance in order to provide useful flux across, for example, an air gap in the high reluctance circuit, the force required to move the magnet will be greatest at the point at which the magnet finally leaves the low reluctance circuit. Thus in arrangements in accordance with the present invention in which the or each magnet is arranged for relative radial movement with respect to a pole piece assembly providing a shunt circuit for the poles of the magnet in one (relative) position thereof and pole pieces excited by the magnet in the other position thereof, the centrifugal force required to effect the relative movement will be greatest at the point where the magnetic circuit shunting the magnet poles is finally broken as the magnet moves towards its position exciting the pole pieces and this will tend to mitigate against a smooth change of coupling effect at this point. If the reluctances of the shunting and coupling circuits can be made more nearly equal a smoother change in coupling effect should be obtained since, theoretically at least, the magnet will be moving between positions in which it has to provide approximately the

same value of flux, and to this end the portions of the pole piece assembly corresponding to 24 in Fig. 4 and 24[1] in Fig. 10 may be grooved transversely of the direction of flux flow therethrough, or otherwise reduced in effective cross-section so as to increase the reluctance of the shunt circuit for the magnet poles to a value approaching or equal to the reluctance of the magnetic circuit through which the flux of the maximum coupling field passes.

In Specification No. 726,835 which bears a date earlier than but was not published at the date of the present Specification, there is claimed a permanent magnetic coupling wherein a weath of permanent magnets is disposed on each of the two coupling halves, the pole faces of which are directed towards the gap in the coupling, characterised in that each of the said permanent magnets consists of an inner part and of an outer part, disposed about a common geometrical axis, the outer surrounding the inner part and being separated therefrom by a layer having low magnetic conductivity, while the two parts are connected by material having high magnetic conductivity on the side facing away from the gap in the coupling, which coupling is further characterised in that the wreath of magnets of the driving half of the coupling is radially displaceable by centrifugal forces relative to the wreath of magnets secured to the driven half of the coupling and is reset by a resetting spring. No claim is made herein to a magnetic coupling so characterised, but subject to this disclaimer what we claim is:—

1. A magnetic coupling device of the kind referred to whereof the part adapted for rotation with a running member (as defined) includes for rotation therewith one or more permanent magnet assemblies (each) arranged to provide opposite poles for a magnetic coupling field and (each) having at least a portion thereof arranged to move under the combined influence of centrifugal force and an opposing spring force between radially displaced positions at which, respectively, maximum and minimum linkage of magnetic flux with the alternate part of the device is obtained, such maximum and minimum linkage corresponding to maximum and minimum coupling effect respectively.

2. A coupling device as claimed in Claim 1 wherein the or each permanent magnet assembly on the one part of the device comprises a permanent magnet arranged for radial movement under the combined action of said centrifugal and opposing forces towards and away from a co-operating, generally cylindrical surface provided on the alternate part of the coupling device coaxially with the rotational axis, the magnet, or pole pieces secured therewith, providing opposite poles at positions spaced transversely of the magnet's movement whereby in the positions of the magnet corresponding to the poles being nearest to and furthest from said surface, there is respectively maximum and minimum linkage of flux with said alternate part of the device.

3. A coupling device as claimed in Claim 2 wherein the magnet is slidably assembled on the appertaining part of the device on a radially extending rod or the like surrounded by a spring for opposing the action of centrifugal force on the magnet.

4. A coupling device as claimed in Claim 2 wherein the magnet is mounted on and intermediately of a spring strip or the like which is carried by the appertaining part of the device in position extending generally lengthwise of the rotational axis and is secured for axial sliding adjacent its opposite ends so as to bow to an extent dependent on the centrifugal force and the strength of the spring and thereby move the magnet radially to a corresponding extent.

5. A coupling device as claimed in Claim 1 wherein the or each permanent magnet assembly on the one part of the device comprises a radially fixed permanent magnet and a pair of pole pieces arranged for radial movement under the combined action of said centrifugal and opposing forces towards and away from a peripheral surface of a co-operating generally cylindrical surface provided on the alternate part of the coupling device coaxially with the rotational axis, which pole pieces are excited with opposite polarity by the permanent magnet and are effectively disposed at positions spaced transversely of their direction of movement whereby in the positions thereof corresponding to their being nearest to and furthest from said surface there is respectively maximum and minimum linkage of flux with said alternate part of the device.

6. A coupling device as claimed in Claim 1 wherein the or each permanent magnet assembly comprises as separate parts thereof a permanent magnet and a pole piece assembly therefor including a pair of pole pieces magnetically isolated from each other, the magnet and the pole piece assembly being arranged for radial movement relatively to each other, under the influence of spring-opposed centrifugal force, between relative radial positions at one of which the magnet induces in the pole pieces a maximum flux producing therebetween a maximum coupling field linking the alternate part of the coupling device, and at the other of which the magnet induces minimum flux in the pole pieces.

7. A coupling device as claimed in Claim 6 wherein in the relative position of the magnet and pole piece assembly corresponding to minimum induction of flux in the

pole pieces, the poles of the magnet are bridged by a magnetic shunt.

8. A coupling device as claimed in Claim 6 or Claim 7 wherein the pole piece assembly of the or each permanent magnet assembly comprises two composite, radially extending members between which the magnet is disposed, for relative radial movement with respect thereto, with its magnetic axis extending in the direction from the one composite member to the other, which members each comprise radially inner and outer portions of magnetic material separated by a substantially non-magnetic portion, with one pair of corresponding magnetic portions in the respective members, namely the outer or inner portions as may be appropriate, arranged to constitute the required pole pieces and with the other pair of corresponding magnetic portions magnetically connected through a magnetic cross-piece, so that when the magnet is in position between the pair of magnetic portions constituting the pole pieces poles are induced therein to produce the magnetic coupling field, whereas when the magnet is in position between the other pair of magnetic portions substantially all the flux from the magnet is shunted through the cross-piece.

9. A coupling device as claimed in Claim 7 or Claim 8 wherein a magnetic member included in the shunt path for the magnet poles in the relative position of the magnet and pole piece assembly corresponding to minimum induction of flux in the pole pieces is grooved transversely of the flux path or otherwise locally reduced in effective cross-sectional area to increase the reluctance of said path to a value approximating to the reluctance of the magnetic circuit through which the flux of the maximum coupling field passes.

10. A coupling device as claimed in any preceding claim comprising a plurality of such permanent magnet assemblies symmetrically disposed around the rotational axis of the device.

11. A coupling device as claimed in any preceding claim including a plurality of such permanent magnet assemblies, or a plurality of sets thereof, arranged to become effective to produce their maximum coupling effects at different speeds of the running member, whereby with increasing or, alternatively, decreasing speed the several assemblies or sets will attain their maximum coupling effects in turn until at a predetermined high or, in the alternative, low speed all are contributing to a total maximum coupling effect.

12. A coupling device as claimed in any preceding claim operable by virtue of eddy currents set up in said alternate part thereof and including a plurality of such permanent magnet assemblies, or a plurality of sets thereof, arranged with different effective diameters so as to become operative at different relative speeds of the running member with respect to a member to be coupled therewith.

13. A magnetic coupling device substantially as hereinbefore described with reference to any one of the examples illustrated in the drawings accompanying the Provisional Specification.

J. W. RIDDING,
Chartered Patent Agent,
64–66 Coleman Street,
London, E.C.2.
Agent for the Applicants.

PROVISIONAL SPECIFICATION.

Improvements relating to Magnetic Coupling Devices including Clutches and Brakes.

We, METROPOLITAN-VICKERS ELECTRICAL COMPANY LIMITED, a British Company, having its Registered Office at St. Paul's Corner, 1—3 St. Paul's Churchyard, London, E.C.4, do hereby declare this invention to be described in the following statement:—

This invention relates to magnetic coupling devices, such as may be used as clutches, brakes, dynamometers and the like, of the kind in which two relatively rotatable co-operating parts maintained in spaced relationship with respect to each other are arranged to be coupled together, namely for the transmission of torque therebetween, by the coupling action of a magnetic field (or fields) set up between a pair (or respective pairs) of opposite poles so disposed in the one part of the device that magnetic flux passing from the one pole to the other traverses the space separating the co-operating parts and links the alternate part. As is well known such coupling action can be obtained by arranging the magnetic field to set up a hysteresis or an eddy current effect or by including in the space between the co-operating parts of the coupling device a magnetic fluid that will tend to become "solidified" on application of a magnetic field thereto.

In using such a coupling device as, for instance, a clutch between two relatively rotatable members, the two co-operating parts of the device will be arranged for rotation respectively with said members,

whereas in using the device for braking a rotating member, one of the co-operating parts will be arranged for rotation with that member and the other part will be fixed against rotation. In the following, the term running member will be used to denote a member from which torque is to be transmitted by the coupling device, whether the transmitted torque is applied to drive a further member or is absorbed by a fixed member to effect a braking action on the running member.

It is often desirable that the extent of the coupling effect provided by a coupling device of the above kind, and thus the braking or driving torque transmitted by the device, shall be controllable in dependence on the speed of the running member, and to this end it has previously been proposed to provide the magnetic field by electromagnetic means and to control the excitation thereof in dependence on said speed. Such control has been obtained for instance by deriving a voltage proportional to speed, as from a permanent magnet generator rotating with the running member, and using that voltage to actuate an electronic device which in turn controls the exciting current for the electro-magnetic means.

Magnetic coupling devices of the kind referred to have also been proposed in which the magnetic field is provided by permanent magnet means, but so far as is known no permanent magnet coupling device has previously been proposed in which the extent of coupling effected is dependent on the speed of a running member with which the coupling device is employed.

According to the present invention in a magnetic coupling device of the kind referred to the part thereof adapted for rotation with a running member (as defined) includes for producing the magnetic field, or fields, by which coupling is effected an appropriate number of permanent magnet assemblies (namely one or more) each of which is arranged to provide opposite poles for a magnetic coupling field and at least a portion of each of which is arranged to move, under the combined influence of centrifugal force and an opposing spring force, between radially displaced positions providing respectively maximum and minimum linkage of magnetic flux with the alternate part of the device, namely corresponding to maximum and minimum coupling effect respectively.

The coupling device may be arranged either to give increasing coupling effect with increasing speed or to give decreasing coupling effect with increasing speed (and vice versa) as may be desired.

The coupling device of the invention thus provides a magnetic coupling effect varying in dependence on the speed of a running member from which torque is to be transmitted, without requiring the use of intermediated electric or electronic means for controlling the excitation of an electromagnet. Also, since the coupling device operates by a centrifugal effect without relying on friction between the co-operating parts thereof for transmitting the torque, it has the advantage that wear between the parts can be substantially reduced as compared with conventional centrifugal brakes or clutches in which spring-loaded masses on the running member are caused by centrifugal force to move radially until they engage a cylindrical surface provided on the alternate member and thereby effect a frictional coupling. Moreover as will appear later it is possible with the coupling device of the invention to obtain flexibility of control which is greater than that obtainable with such conventional centrifugal devices operating by friction.

In one way of carrying out the invention the or each permanent magnet assembly may comprise a permanent magnet arranged for radial movement under the combined action of said centrifugal and opposing forces towards and away from the peripheral surface of a co-operating, generally cylindrical portion provided on the alternate part of the coupling device coaxial with the rotational axis thereof, the magnet, or pole pieces thereon, providing opposite poles at positions spaced transversely of the magnet's movement whereby in the positions of the magnet corresponding to the poles being nearest to and further from said surface, there is respectively maximum and minimum linkage of flux with such cylindrical portion and thus maximum and minimum coupling effect.

To this end the magnet may be slidably assembled on the appertaining part of the coupling device on a radially extending rod or the like surrounded by a spring for opposing the action of centrifugal force on the magnet. Alternatively, especially where the coupling device is to constitute a brake, the magnet may be mounted on and intermediately of a spring strip or the like which extends generally lengthwise of the rotational axis and is secured for axial sliding adjacent its opposite ends so as to bow to an extent dependent on the centrifugal force and thereby move the magnet radially as required. It is also contemplated that the permanent magnet may be radially fixed with pole pieces permanently excited thereby arranged for radial movement in the manner just described for the magnet.

In another way of carrying out the invention the or each permanent magnet assembly may comprise a permanent magnet together with pole pieces therefor provided on a separate part of the assembly and mag-

netically isolated from each other, the magnet and the pole pieces being arranged for radial movement relatively to each other, under the influence of spring-opposed centrifugal force, between relative radial positions at one of which the magnet induces maximum flux in the pole pieces to produce therebetween a maximum coupling field linking the alternate part of the coupling device, and at the other of which the magnet induces minimum flux in the pole pieces. Preferably in this latter relative position of the magnet and pole pieces the magnet poles are bridged by a magnetic shunt to ensure negligible magnetic field between the pole pieces.

Thus the part of the magnet assembly providing the pole pieces may comprise two composite, radially extending members between which the magnet is disposed for radial movement relatively thereto with its magnetic axis extending in the direction from the one composite member to the other, which members each comprise radially inner and outer portions of magnetic material separated by a substantially non-magnetic portion, with one pair of corresponding magnetic portions in the respective members, namely the outer or inner portions as may be appropriate, arranged to constitute the required pole pieces and with the other pair of corresponding magnetic portions magnetically connected through a magnetic cross piece so that when the magnet is in position between the pair of magnet portions constituting the pole pieces poles are induced therein to produce a magnetic coupling field, whereas when the magnet is in position between the other pair of magnetic portions substantially all the flux from the magnet is shunted through the cross-piece.

The part of the magnet assembly providing the pole pieces may be radially fixed and the magnet arranged to be moved radially under the combined influence of centrifugal and opposing spring force, or alternatively the magnet may be radially fixed and the part providing the pole pieces arranged to be moved radially under the influence of said forces, in which latter case it will usually be arranged that the spacing of the pole pieces from the alternate part of the coupling device remains substantially constant throughout their movement.

The coupling characteristics obtained with a device in accordance with the invention depends on a number of factors by separate or combined adjustment of which a variation of performance can be obtained. Thus the coupling characteristics will depend on:—

(1) the magnet strength;

(2) the shape of the magnetic poles or of the space traversed by the flux between the co-operating parts of the device, variation in these producing a variety of flux-to-gap-length characteristics;

(3) the strength and design of the spring(s) providing the force opposing the centrifugal force;

(4) whether or not air bleed or pneumatic damping is provided for;

(5) the weight of the parts moving under centrifugal action, it being contemplated that this can be adjusted if desired by the addition of non-magnetic weights to such parts.

It is contemplated that usually a number of permanent magnet assemblies as above described will be symmetrically disposed about the rotational axis of the coupling device to form a set. Moreover it may sometimes be useful to have a number of magnet assemblies, or sets thereof, arranged to become effective at different speeds so that with increasing (or, alternatively, decreasing) speed, the various assemblies or sets will attain their maximum coupling effects in turn, until at a predetermined high (or, in the alternative, low) speed all are contributing to the total coupling effect. Furthermore in the case of an eddy current coupling device in accordance with the invention, a number of magnet assemblies, or sets thereof, may be arranged so as to have different effective diameters: since the eddy current drag is proportional to peripheral speed, each assembly, or set, will come into operation at different angular speeds of the running member.

For a fuller understanding of the invention reference may now be had to the accompanying drawings in which:—

Figs. 1 and 2 illustrate a magnetic clutch according to the invention, Fig. 1 being a section on the line X—X of Fig. 2;

Fig. 3 illustrates a magnetic brake according to the invention;

Figs. 4 and 5 illustrate an alternative arrangement to that of Figs. 1 and 2, Fig. 4 being a section on the line Y—Y of Fig. 5;

Figs. 6 and 7 illustrate respectively possible ways in which the arrangement of Figs. 4 and 5 could be modified to provide different coupling characteristics; and

Figs. 8, 9 and 10 illustrate further alternative arrangements of magnetic clutch in accordance with the invention.

In Figs. 1 and 2 a number of U-shaped permanent magnets 1 are able to move radially with respect to a driving shaft 2 along non-magnetic guides 3, the movement of the magnets being controlled by springs 4 which abut against stops 5 at the ends of the guides 3 remote from the shaft. When the driving shaft is stationary, the magnets, under the restraining action of the springs, assume the inner positions as shown in the figures, but when the driving shaft is rotated, the centrifugal force acting on the magnets will cause them to slide along the guides 3,

thereby decreasing the width of the gaps between the poles of the magnets and a cylindrical portion 6 formed integrally with a flange 7 carried by a shaft 8 to be driven. Thus as the speed of the driving shaft increases the amount of magnetic flux crossing the gaps to link the portion 6 will also increase thereby in turn to increase the coupling effect and thus the torque transmitted to the shaft 8. It will be noted that the relation between the speed and the torque will be non-linear since the force moving the magnets is proportional to the square of speed and the flux increases rapidly as the gaps diminish in width. Thus, the driving torque is proportional to an *n*th power of speed where *n* is greater than unity and may be, say, 3 or 4.

In will be appreciated that if the rimmed flange 7 were fixed against rotation, or if it were replaced by, say, a fixed cylinder surrounding the magnet assemblies, an increasing braking torque would be applied to the shaft 1 with increasing speed thereof, the torque being again proportioned to, say, the third or fourth power of the speed.

Fig. 3 illustrates the invention incorporated in a brake. U-shaped magnets 9 are bolted to leaf springs 10 the ends of which are fastened to two collars 11, 12 keyed to, but slidable axially on, a rotatable shaft 13 to be braked. The magnets are surrounded by a fixed metal cylinder 14 which acts in conjunction with the magnets to provide a braking effect of magnitude dependent among other factors, on the width of the gaps between the magnet poles and the cylinder 14. Grooves 15, 16 of limited length are provided on the shaft to engage with keys on the collars 11 and 12 thereby preventing the collars from rotating with respect to the shaft and also preventing the magnets from touching the cylinder 14.

It may be desirable in certain cases to have negligible drag or drive up to a certain speed, and a full braking effect or driving torque at speeds above that critical value. This may be obtained by an arrangement on the lines of that shown in Figs. 4 and 5, which arrangement constitutes a clutch but could readily be modified as a brake. In these Figures a number of permanent magnets 17 are constrained to move radially, with respect to a driving shaft 18, by pegs 19 engaging with slots 20 in radially extending members 21, their movement being controlled by springs 22 which react against fixed non-magnetic parts 23 at the outer ends of the members 21. The members 21 are composite members comprising radially inner and outer portions, 24 and 27 respectively, which are of magnetic material such as mild steel and are separated from each other by non-magnetic portions 26 as of brass. When the driving shaft is stationary the magnets assume the positions shown and substantially all of the magnetic flux from the magnet circulates through the inner portions 24 of the members 21 and a magnetic cross-piece 25, the portions 26 of non-magnetic material preventing the flux from reaching the outer portions 27 of the members 21. However, as the speed of the driving shaft increases, the magnets 17 move out radially against the springs until, at a certain speed, they pass the non-magnetic sections 26 and induce opposite poles in the appertaining outer portions 27 which then constitute pole pieces for the magnets and provide a magnetic flux linking a rimmed flange 28 on the driven shaft 29 and thereby producing a coupling effect driving the shaft 29. Similarly, when the speed of the driving shaft decreases, the coupling decreases until the magnets pass the portions 26 when the coupling becomes negligible. The characteristics of this drive may be adjusted by the methods listed above and also, as shown diagrammatically in Figs. 6 and 7, by shaping the magnets.

The arrangements described in connection with Figs. 1—5 are such as to give increased coupling effect with increased speed. It is also contemplated that the coupling effect could be arranged to be a minimum at high speed and a maximum at low speeds and possible ways of doing this are illustrated in Figs. 8—10.

Figs. 8 and 9 are merely inversions of the arrangements of Figs. 1 and 4 respectively and their construction and operation will be readily understood without further description. The arrangement of Fig. 10 is similar to that of Fig. 9 except that the magnets 17^1 are radially fixed while the composite radially extending members 21^1, which are similar to the corresponding members 21 of Fig. 4 in that they have radially inner and outer magnetic portions 24^1 and 27^1, an intermediate non-magnetic portion 26 and a cross-piece 25^1, are constrained to move outwardly against a spring action under the influence of centrifugal force. It will be noted in Fig. 10 that the members 21^1 are arranged so that the outer ends of the portions 27^1 (namely at which the poles are induced) move between the flange 7^1 and an inwardly extending flange 30 in such manner that the gaps at the poles remain substantially constant throughout the movement of the members 21^1.

The arrangement illustrated in the various figures of the drawings may be arranged in known manner so as to provide the required coupling either by a hysteresis effect or by a combination of these. Alternatively or in addition the gaps between the poles set up in the one part of the coupling device and the alternate part of the device may be filled

with a magnetic fluid such as will tend to "solidify" to provide a coupling effect on the application of a magnetic field thereto. Suitable materials for the permanent magnets are those known by the trade names "Alcomax" and Columax".

As is well known, if a magnet is moved from a circuit of low magnetic reluctance to one of relatively high reluctance in order to provide useful flux across, for example, an air gap in the high reluctance circuit, the force required to move the magnet will be greatest at the point at which the magnet finally leaves the low reluctance circuit. Thus in arrangements in accordance with the present invention in which the or each magnet is arranged for relative radial movement with respect to a pole-piece assembly providing a shunt circuit for the poles of the magnet in one (relative) position thereof and pole-pieces excited by the magnet in the other position thereof, the centrifugal force required to effect the relative movement will be greatest at the point where the magnetic circuit shunting the magnet poles is finally broken as the magnet moves towards its position exciting the pole-pieces and this will tend to mitigate against a smooth change of coupling effect at this point. If the reluctances of the shunting and coupling circuits can be made more nearly equal a smoother change in coupling effect should be obtained since, theoretically at least, the magnet will be moving between positions in which it has to provide approximately the same value of flux, and to this end the portions of the pole-piece assembly corresponding to 24 in Fig. 4 and 24[1] in Fig. 10 may be grooved transversely of the direction of flux flow therethrough so as to increase the reluctance of the shunt circuit for the magnet poles to a value approaching or equal to the reluctance of the magnetic circuit through which the flux for the coupling field passes.

J. W. RIDDING,
Chartered Patent Agent,
64–66 Coleman Street,
London, E.C.2.
Agent for the Applicants.

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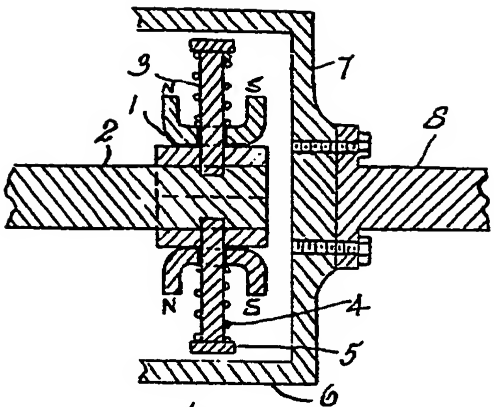

FIG.1.

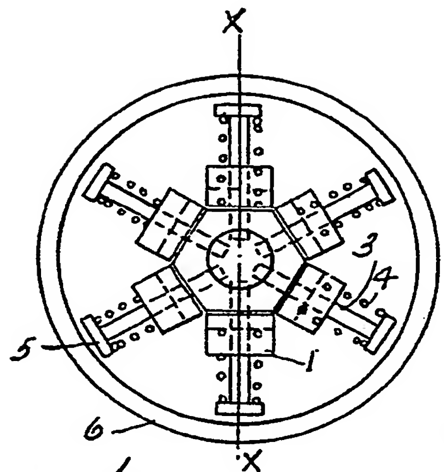

FIG.2.

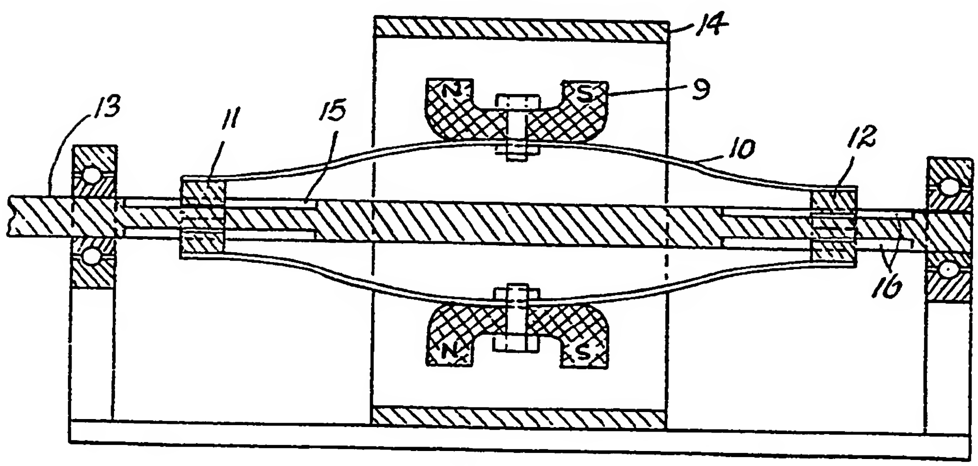

FIG.3.

765,586 PROVISIONAL SPECIFICATION
2 SHEETS

This drawing is a reproduction of the Original on a reduced scale.
SHEETS 1 & 2

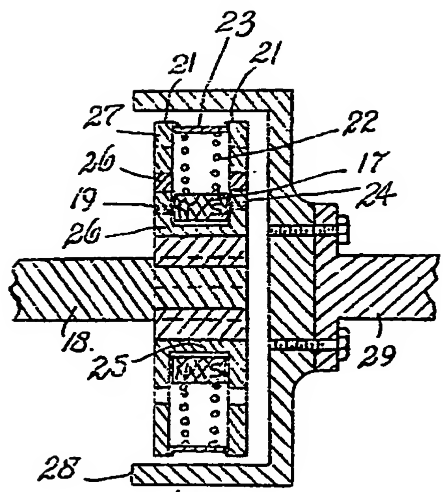

FIG.4.

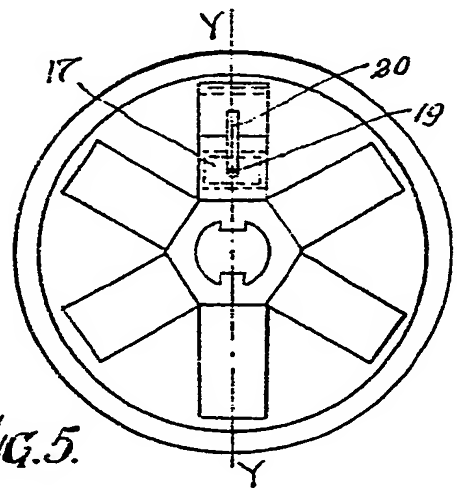

FIG.5.

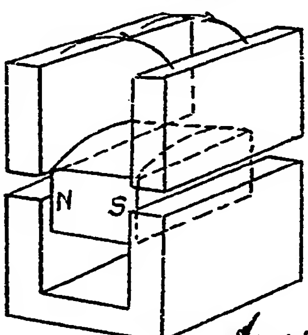

FIG.6.

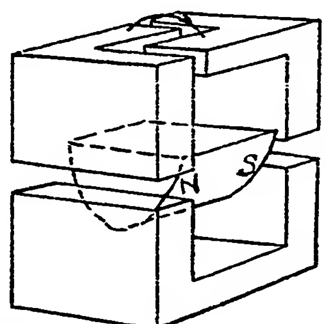

FIG.7.

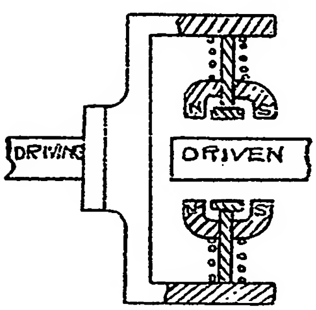

FIG.8.

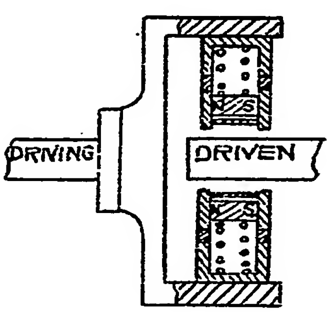

FIG.9.

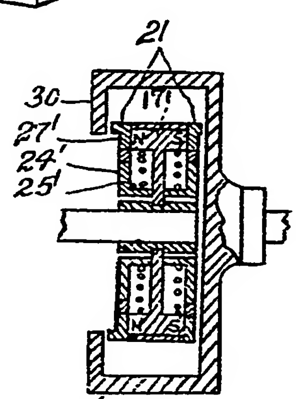

FIG.10

765,586 PROVISIONAL SPECIFICATION
2 SHEETS
This drawing is a reproduction of the Original on a reduced scale.
SHEETS 1 & 2

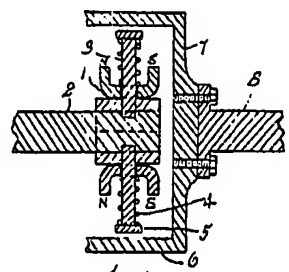

FIG.1.

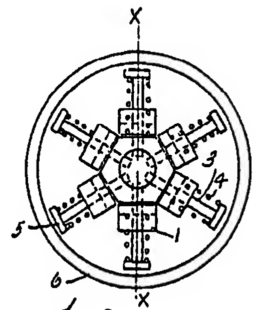

FIG.2.

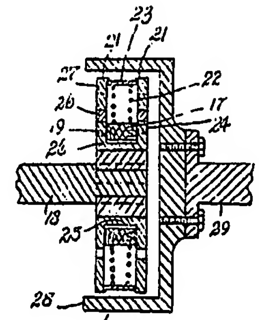

FIG.4.

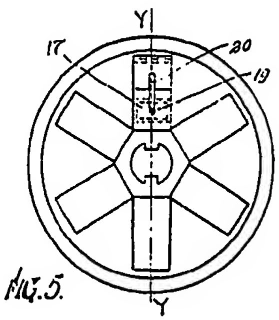

FIG.5.

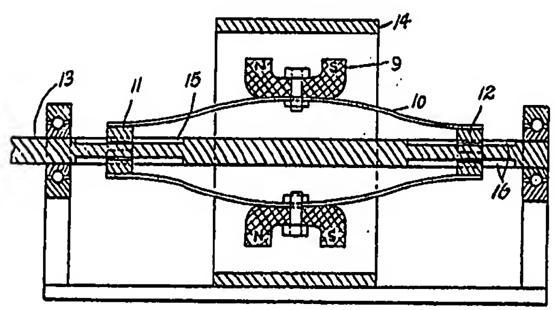

FIG.3.

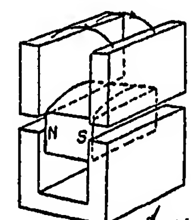

FIG.6.

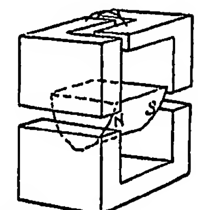

FIG.7.

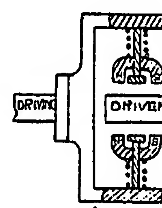

FIG.8.

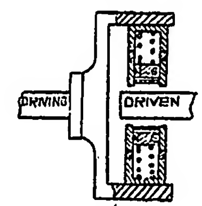

FIG.9.

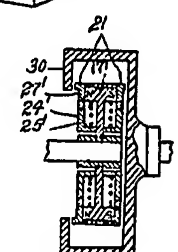

FIG.10